DOE Hydrogen Program

Automotive Cryogenic Capable Pressure Vessels for Compact, High Dormancy (L)H_2 Storage

Salvador Aceves, Gene Berry,
Francisco Espinosa, Tim Ross,
Vernon Switzer, Andrew Weisberg,
Elias Ledesma-Orozco
Lawrence Livermore National Laboratory

June 10, 2008

Project ID # TV9

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Start date: **October 2004**
- End date: **September 2011**
- Percent complete: **60%**

Barriers

- **A. Volume and weight**
- **O. Hydrogen boil-off**

Targets

- **2010 DOE volume target**
- **2010 DOE weight target**

Budget

- Total project funding
  - DOE: **$2500 k**
- Funding received in FY08:
  - **$800 k**
- Funding for FY07:
  - **$750 k**

Partners

- Finalizing **CRADA** with major automobile manufacturer
- Negotiating **CRADA** with major pressure vessel manufacturer

Objective: Demonstrate the practical advantages of cryogenic capable pressure vessels

High energy density

No evaporative losses

Flexible refueling

safe

Milestones: We have made considerable progress toward demonstrating the practicality of cryogenic pressure vessels

- ***Install pressure vessel in experimental Prius vehicle*** **(November 2006)**
- ***Demonstrate long vehicle range:*** **Drove 650 miles on a single H_2 tank (January 2007)**
- ***Resolved technical risk of dormancy & high pressure:*** **Demonstrated potential for 3 weeks dormancy. Test cut short at 6 days due to valve (January 2008)**
- ***Demonstrating vacuum stability:*** **Stable vacuum measured at 10^{-5} torr or below as vessel warms from 30 K to ambient over ~ 1 month. Currently at 200 K (April 2008)**

Approach: Study crucial aspects of cryogenic pressure vessels as onboard storage *systems*

dormancy

vacuum stability

outgassing

cycle test

Accomplishments: We integrated our cryogenic pressure vessel onboard an experimental hydrogen vehicle & demonstrated record unrefueled driving range (650 miles)

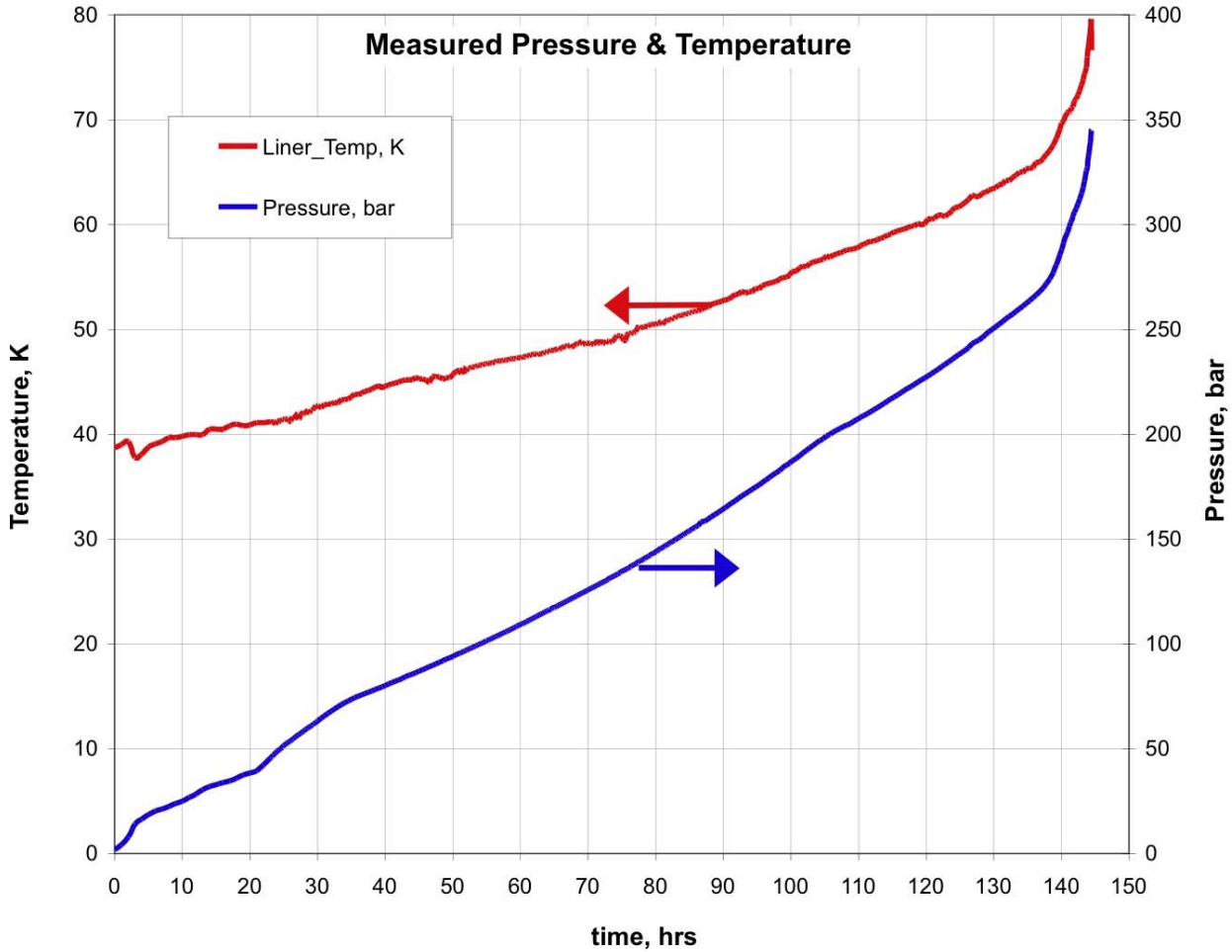
LLNL Cryotank

- Within 10% of DOE 2007 volume using LH_2 and including all system components
- Meets DOE 2007 weight goal
- stores 10.7 kg LH_2 (151 L capacity)
- stores 3.5 kg H_2 at 300 K, 5000 psi

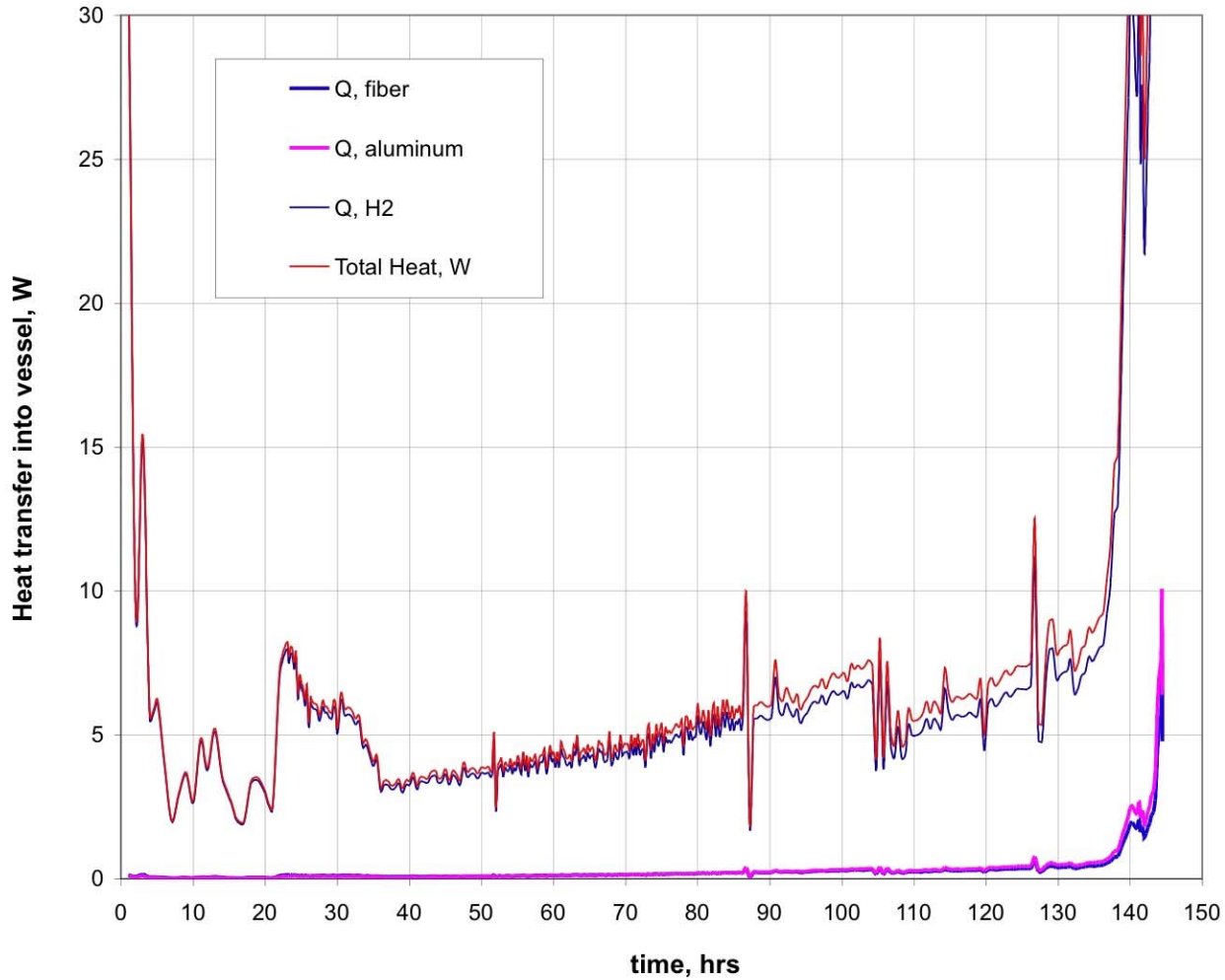
The vehicle

- Toyota Prius converted to H_2 fuel by Quantum Technologies.
- Originally equipped with 5000 psi 68 L pressure vessels (1.6 kg H_2)
- Increased capacity to a single 151 liter vessel (3.5-10.7 kg)

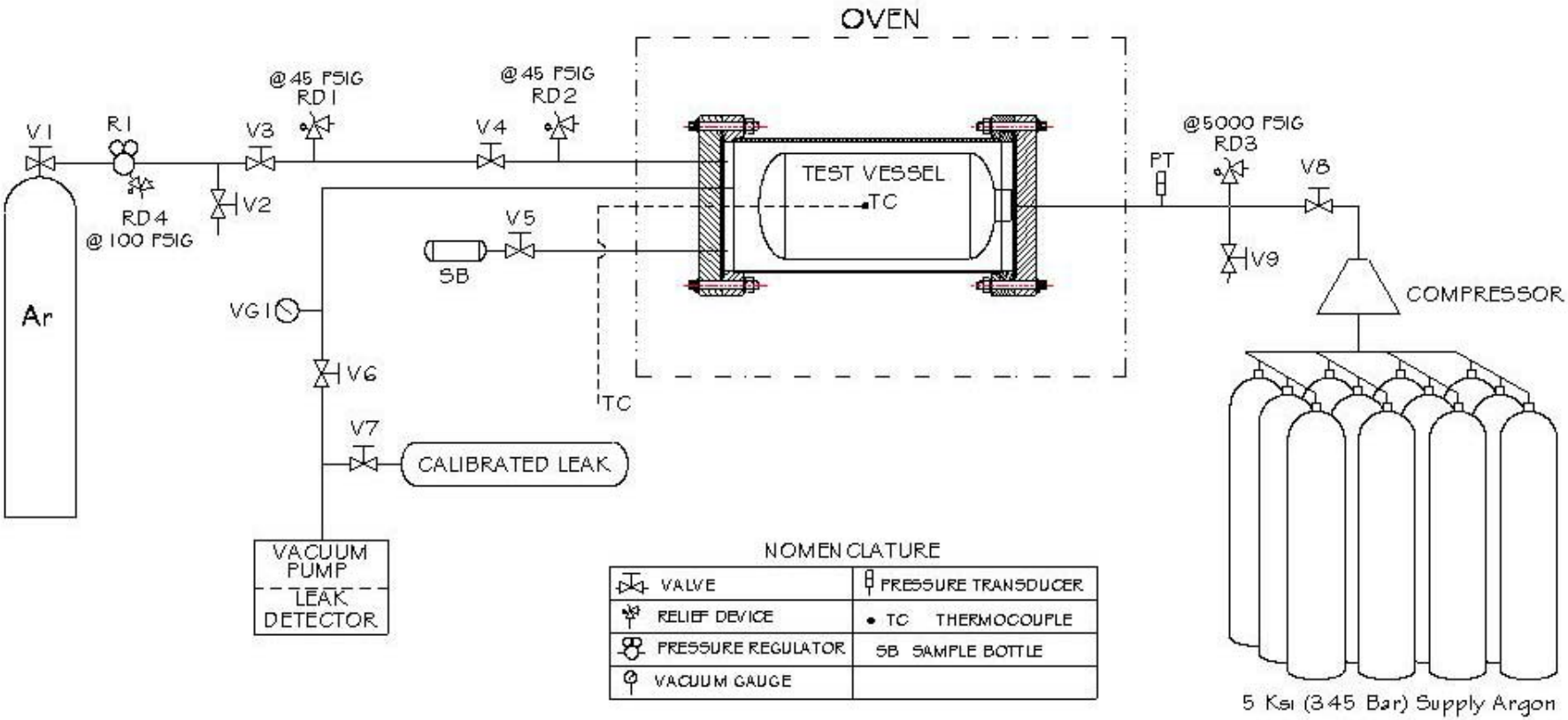
We demonstrated longest LH_2 dormancy onboard a vehicle (6 days) and potential for 3 weeks at ~3.5 Watts heat transfer rate



We demonstrated longest LH_2 dormancy onboard a vehicle (6 days) and potential for 3 weeks at ~3.5 Watts heat transfer rate



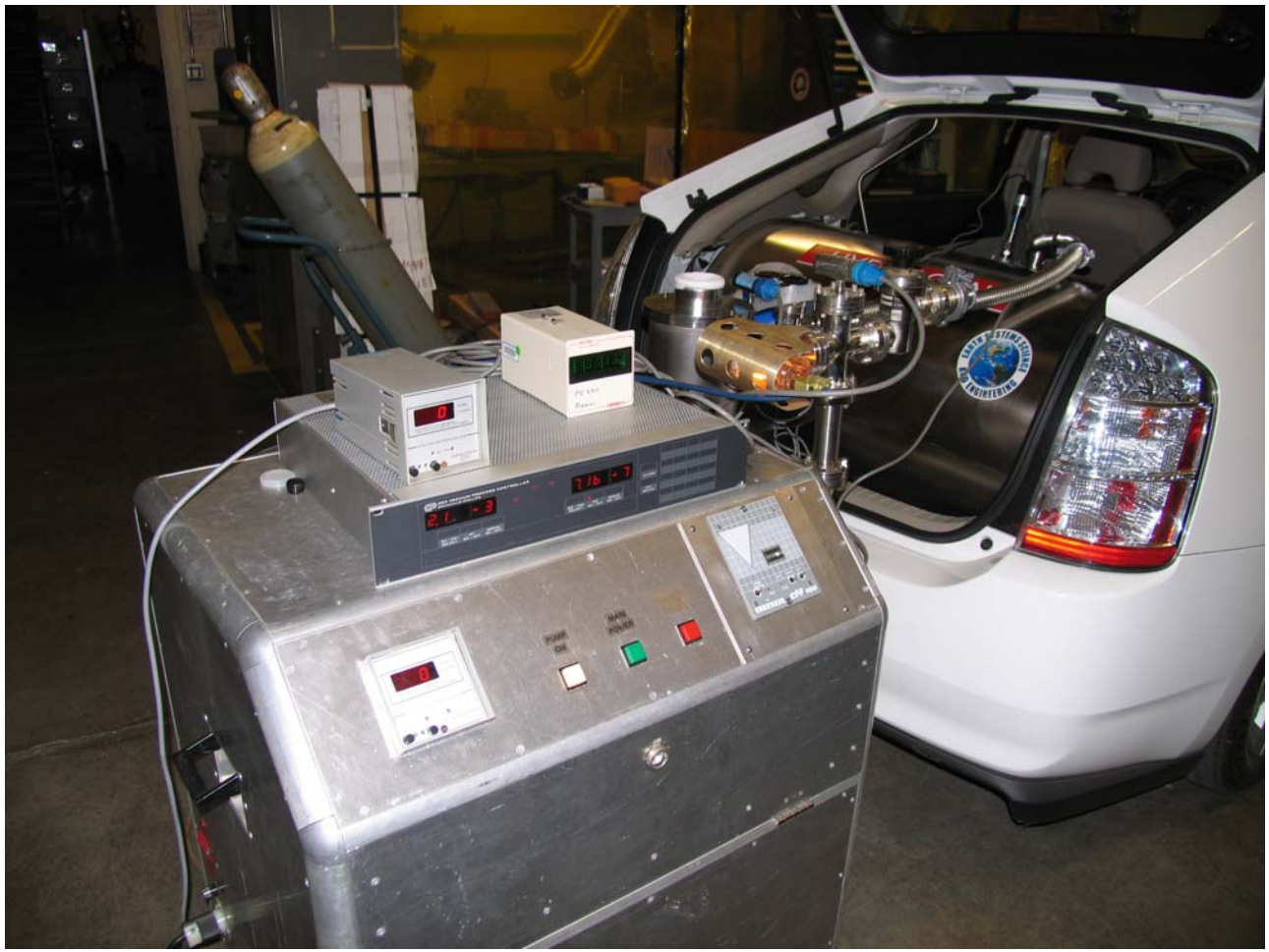
Vacuum stability is a key issue for cryogenic vessels. We are measuring outgassing from the surface of vessels with multiple surface treatments



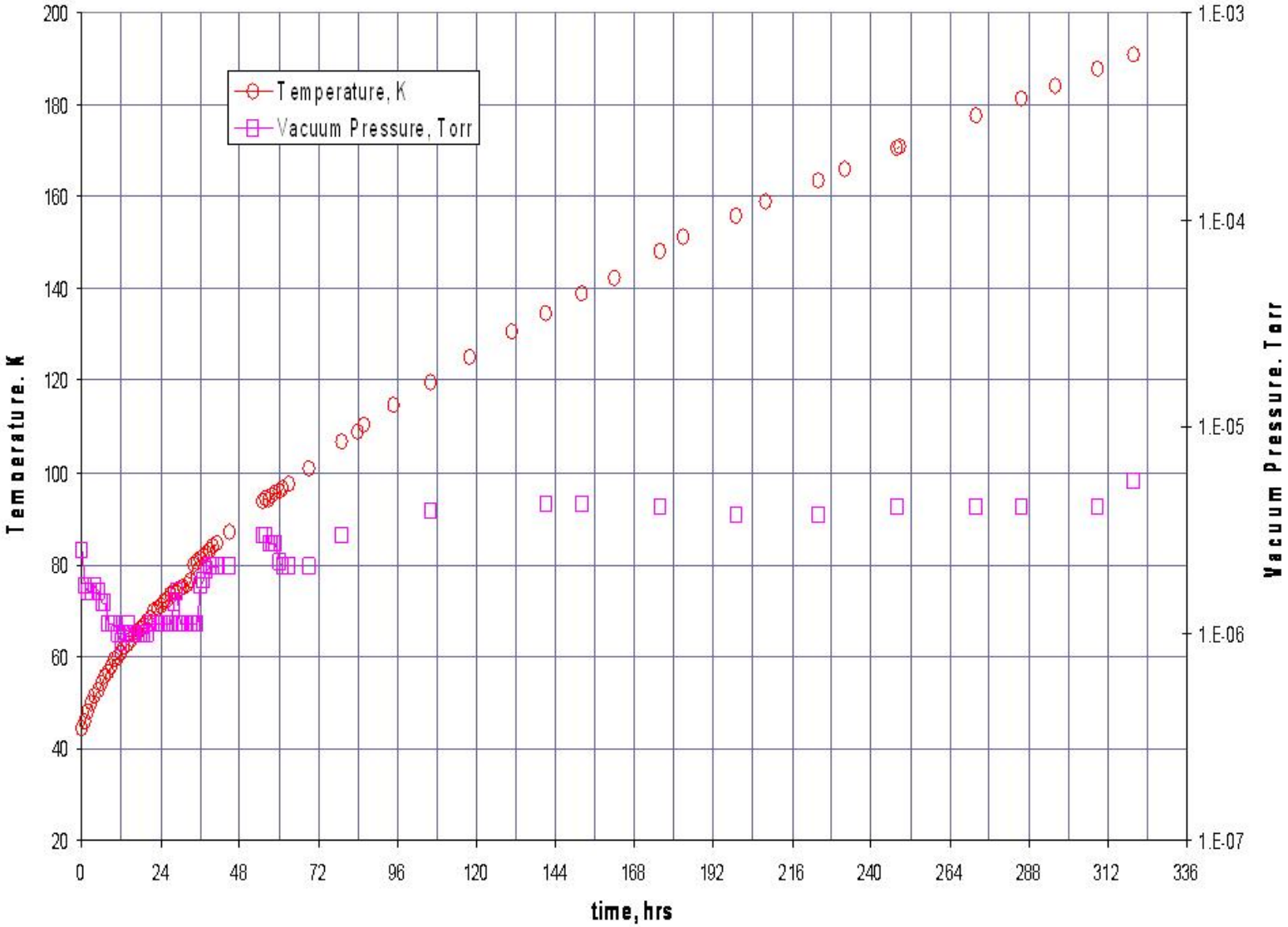
We are conducting outgassing experiments inside an oven installed within a high pressure cell

System was fully built, tested and baked. Three sets of experiments have been run.

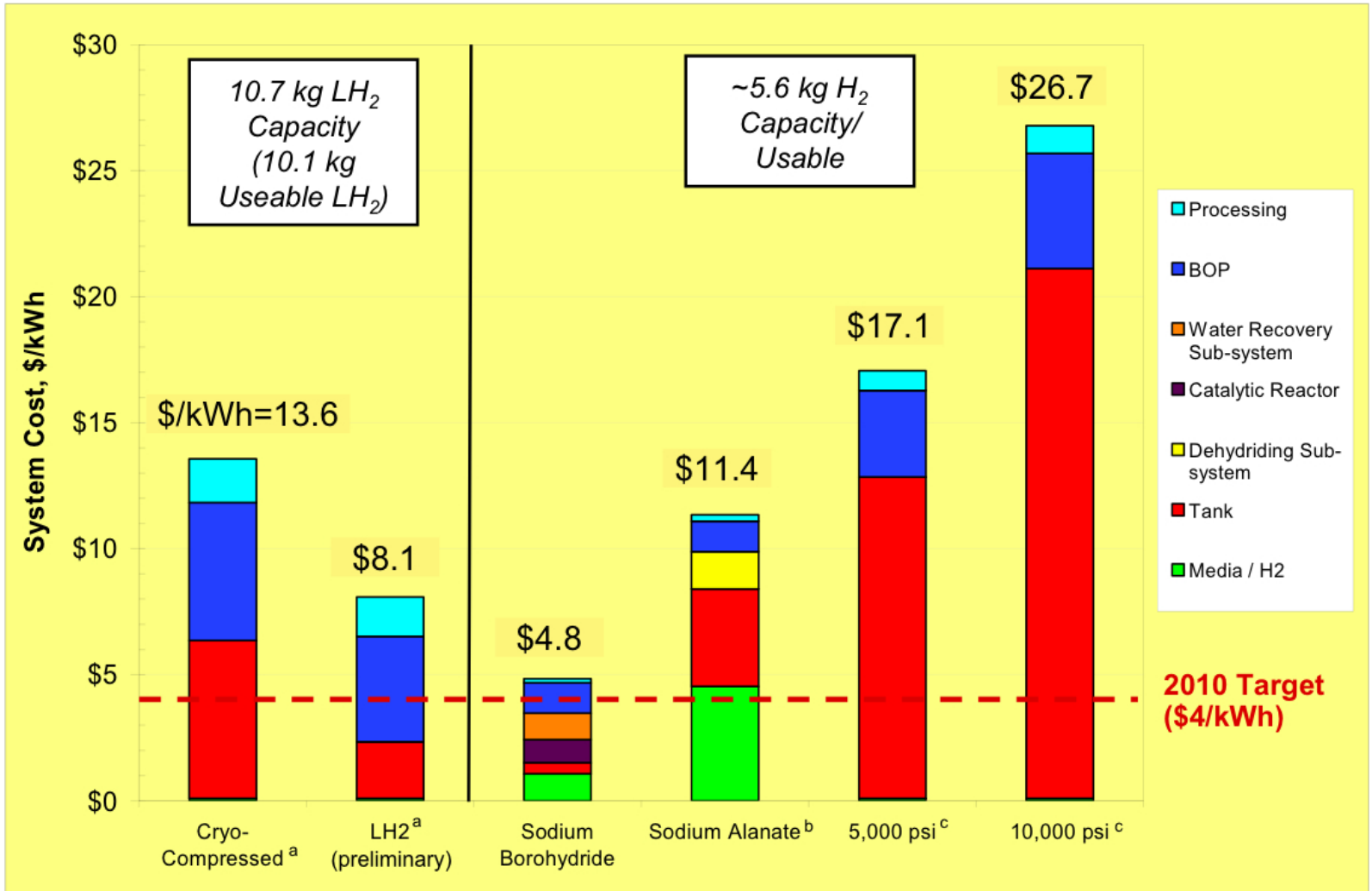
At the request of our industrial partner, we have monitored vacuum quality over a month as our vessel warmed up from cryogenic to ambient temperature



Our experimental results to date indicate good vacuum stability as the vessel warms up from 30 K to 200 K

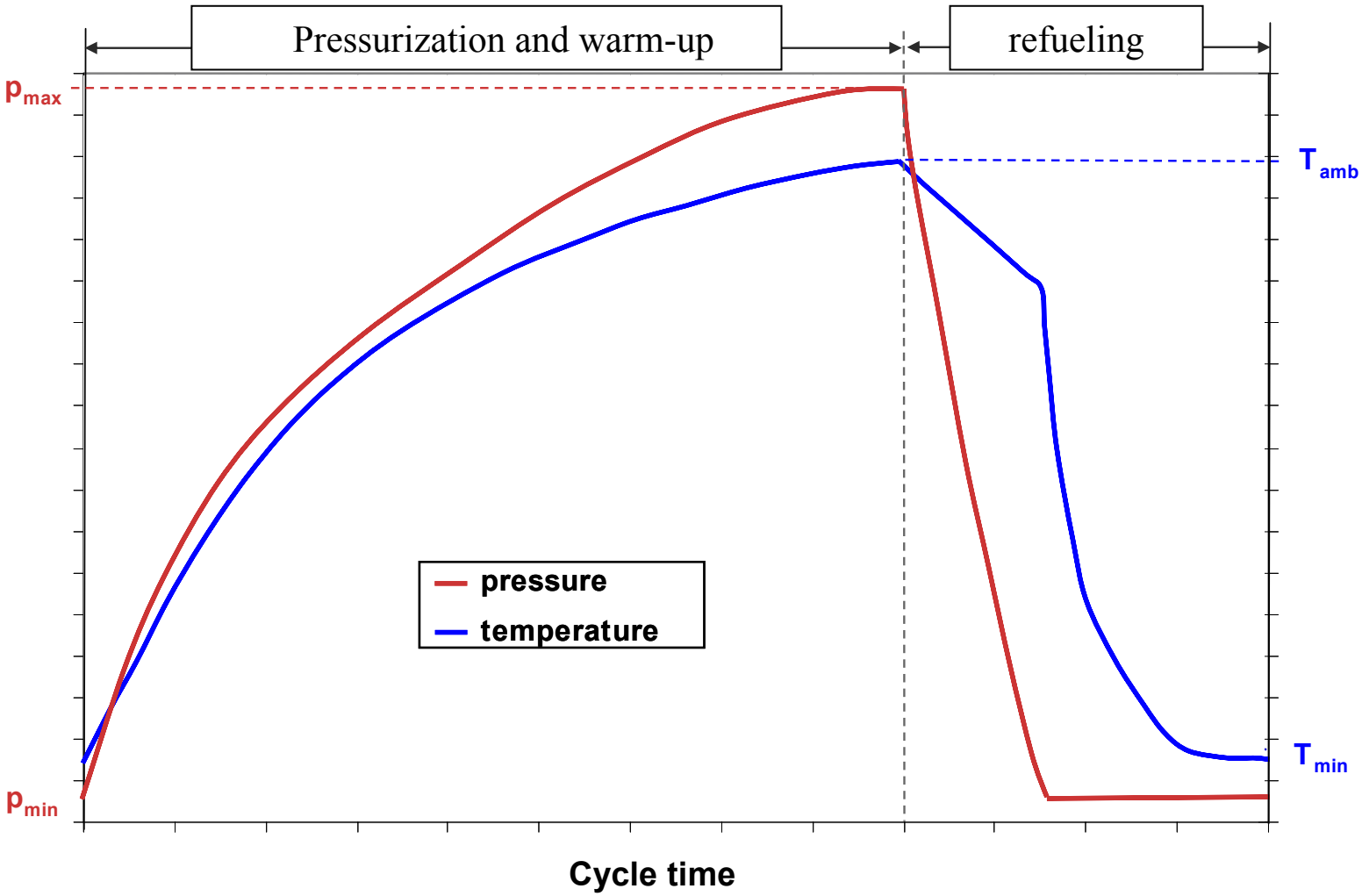


Our cryogenic capable pressure vessels are projected to be less expensive than compressed hydrogen vessels

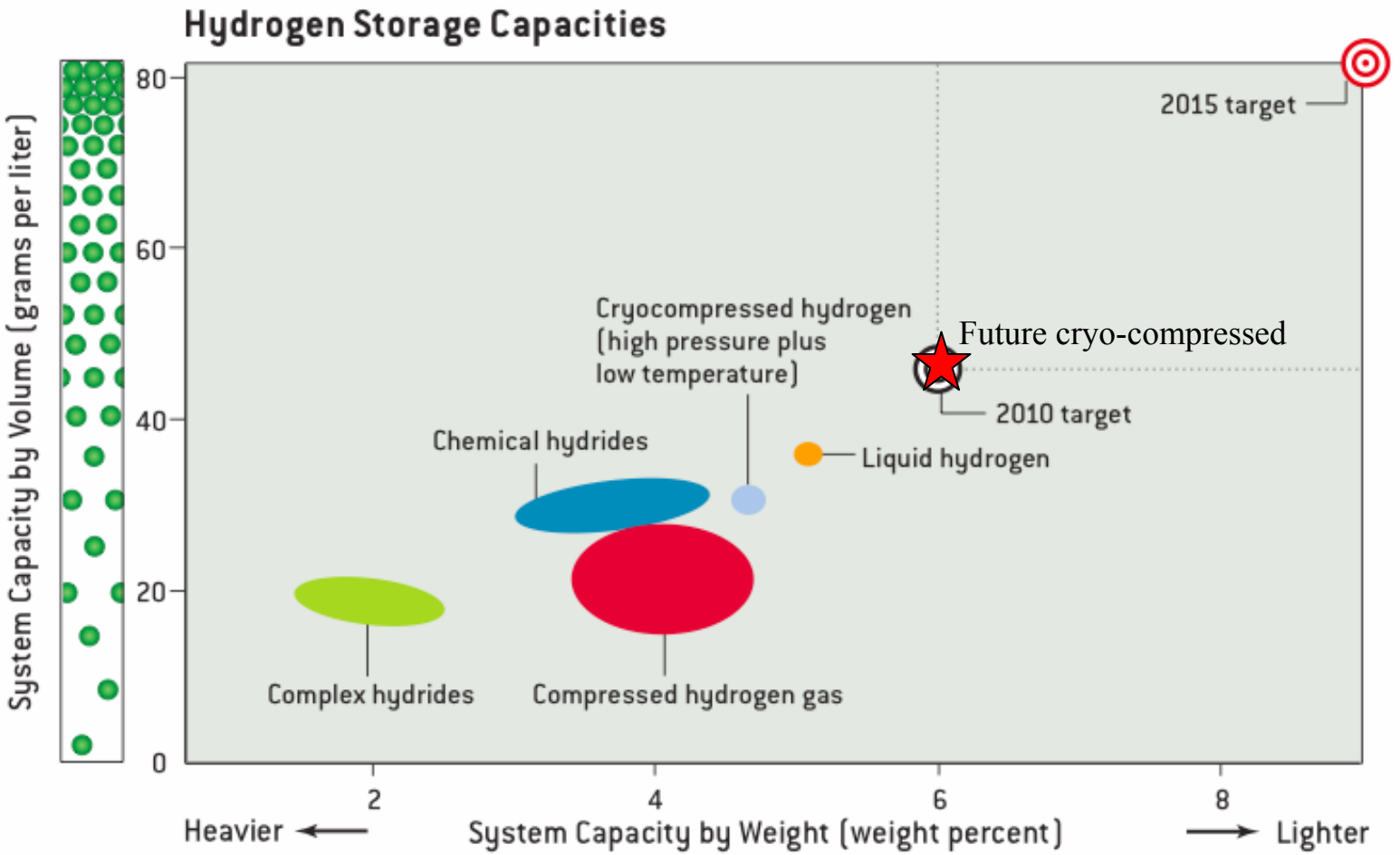


Source: TIAX

Future plans: In collaboration with our industrial partners, design and manufacture a new cryogenic pressure vessel for full cycle testing



Future plans: we will build and demonstrate a cryogenic capable onboard storage system meeting 2010 weight & volume targets



Summary: We will demonstrate the most compact and we believe ultimately practical hydrogen storage technology

- ***The high capacity of liquid hydrogen vessels without the evaporative losses:*** **~10X longer thermal endurance than low pressure LH_2 tanks essentially eliminates boil-off.**
- ***Less expensive than compressed hydrogen vessels:*** **LH_2 capable vessels use 2-3x less carbon fiber than conventional compressed H_2 vessels.**
- ***Refueling flexibility yields infrastructure and driver advantages:*** **Meets real time driver priorities (range, cost, ease, energy) and increases fuel availability**